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THERMOKINETICS IN ANAEROBIC DIGESTION

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Title of Project: Thermokinetics in Anaerobic Digestion

Original Aims and Achievement

The aims of this study were to determine the effects of varying temperature, loading, and substrate composition on anaerobic digestion when the process is closely controlled. Also desired was a determination of whether the organisms producing the reactions in the process fall into obligate temperature categories or are facultative with respect to temperature, and a determination of the reaction rates in the decomposition of fats, carbohydrates and proteins during the process.

The effect of temperature variation upon the high-rate anaerobic digestion process has been studied with all other variables maintained under carefully controlled conditions, including the composition of the feed.

Complete mixing of digester contents was accomplished by gas recirculation, and temperatures of the digesters were controlled with constant temperature water baths. Both the mesophilic and thermophilic ranges were studied by covering the range of temperatures from 95F to 140F in five degree increments. This study showed the optimum

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thermophilic temperature to be between 125F and 130F, and the bacteria to be facultative rather than obligative in character. With the laboratory digesters operating at the optimum thermophilic temperature, a study was made to determine the effect of loading upon the digester performance. The variation in loading was accomplished through operation of the digesters at various retention cycles. These studies indicated a minimum retention time of 8 days was possible without appreciable change in the digester performance.

The next phase of the study dealt with the effect of variation in the composition of the substrate, i.e., variation in fat, carbohydrate and protein content of the digester feed. This would be accomplished by the addition of these individual components to the basic substrate. Unfortunately this phase of the project could not be completed. A great deal of time and effort was expended in attempting to arrive at analytical procedures which would result in accurate, reproducible determinations of the basic components of the digestion products and feed. Work in this area was still under way when the project was terminated.

Discussion

The results obtained during the first phase of the study showed very little change in digester performance over the temperatures 95F to 135F, but a decided drop in performance at 140F. The judgment of performance was based upon gas production, gas quality and volatile solids reduction. In the 95F to 135F range, gas production varied from 231 cc/hr. to 259 cc/hr., (dry gas at 25C, 1 atm.), and the methane content varied from 62.3 per cent to 64.0 per cent while the volatile solids reduction varied from 74.8 per cent to 77.4 per cent. Although there is only a small variation in performance with temperature, an optimum thermophilic temperature is indicated between 125F and 130F. These findings are similar to those of Golueke, (Sewage and Industrial Wastes 30, 1225 (1958) who covered approximately the same temperature range but used a 30-day retention period without continuous mixing. The lack of any sharp discontinuity in digester performance over the temperature range covered suggests that the bacteria responsible for digestion seem to fit the characterization of facultative rather than of obligate thermophiles.

The substrate used throughout this study was a dry animal feed of known composition and available in sufficient quantity to insure the uniformity of substrate fed to the digesters. In addition to the advantage of providing a uniform feed, this material would make it possible to vary the composition of the feed a known amount by adding individual fats, carbohydrates or proteins to the basic substrate, and thus study the effect of varying feeds on digester performance. This would be difficult to accomplish quantitatively with a regular sewage sludge over any period of time.

Although the phase of study dealing with variation in substrate composition could not be completed, an effect of feed composition was apparent at the initiation of the study. The original animal feed used contained 66 per cent carbohydrate and 24 per cent protein. With this feed it was impossible to attain digester equilibrium. Liming, seed rotation, extended periods of no feeding and changing from 5 per cent to 2 per cent solids in the feed concentration were various methods attempted to bring the digesters to equilibrium. It was not until the composition of the feed was changed to 55 per cent carbohydrate, 36 per cent protein that equilibrium was reached and maintained in the digesters without any difficulty. The high carbohydrate concentration in the original feed resulted in a rapid build-up of volatile acids and the ultimate failure of the digesters.

Decreasing the retention time from 10 days to 8 days, while operating at 130F and keeping all other variables constant had no appreciable effect upon the digester performance. At 7 days retention, while gas production increased, the gas quality fell off and the volatile solids removed decreased appreciably; however, it was still possible to maintain equilibrium conditions. It would seem that 8 days is the minimum retention time possible. This is equivalent to a loading of 0.14 lb. of volatile matter per cubic foot of digester contents as compared to 0.11 lb/ft^3 at the ten day retention.

The loading was relatively low in total solids (2%), however the volatile solids concentration in the feed was high (90%) and this resulted in a relatively high volatile matter loading for the digesters. This feed with a high percentage of volatile solids

explains the rather high percentage removal of volatile solids and the high gas production rate.

A preliminary study on the metabolism of amino acids to gaseous products by sludge bacteria was undertaken as part of the second phase of this study. Sludge bacteria were separated from the sludge by successive centrifugations, the final one being at 14,400 rpm. These bacteria were then placed in a Warburg apparatus at 47C with various amino acids, and the reaction observed for 20 minutes. The results show that neither of the sulfur containing amino acids, cystine or methionine, underwent a reaction to a gaseous product. The data imply that these amino acids are not even allowed to pass through the cell wall. Arginine also failed to give a gaseous product, but this was not unexpected since it is a condensation product of urea and ornithine. Leucine also failed to yield gaseous products; however, the structurally similar acids of isoleucine and valine did yield gaseous products.

Alanine, glutamate, aspartate, and histidine appear to have Michaelis kinetics, and probably have free access to the cell, i.e., they probably require no permease to enter the cell. The reactions dealt with here are most likely decarboxylation reactions yielding CO_2 as the gaseous product.

Insufficient data were obtained to allow determinations of the reaction rates in the decomposition of fats, carbohydrates and proteins during the process.

A paper presenting the findings of this study will be submitted for publication in the near future.